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Guide for Conducting Treatability Studies under CERCLA: Thermal Desorption

Office of Emergency and Remedial Response
Hazardous Site Control Division OS-220

QUICK REFERENCE FACT SHEET

Section 121 (b) of CERCLA mandates EPA to select remedies that "utilize permanent solutions and alternative treatment technologies or resource recovery technologies to the maximum extent practicable" and to prefer remedial actions in which treatment that "permanently and significantly reduces the volume, toxicity, or mobility of hazardous substances, pollutants, and contaminants is a principal element." Treatability studies provide data to support remedy selection and implementation. They should be performed as soon as it becomes evident that the available information is insufficient to ensure the quality of the decision. Conducting treatability studies early in the remedial investigation/ feasibility study (RI/FS) process should reduce uncertainties associated with selecting the remedy and should provide a sound basis for the Record of Decision (ROD). Regional planning should factor in the time and resources required for these studies.

This fact sheet provides a summary of information to facilitate the planning and execution of thermal desorption remedy screening and remedy selection treatability studies in support of the RI/FS and the remedial design/remedial action (RD/RA) processes. Detailed information on designing and implementing remedy screening and remedy selection treatability studies for thermal desorption is provided in the "Guide for Conducting Treatability Studies Under CERCLA: Thermal Desorption," Interim Guidance, EPA/540/R-92/074 A, September, 1992.

INTRODUCTION

There are three levels or tiers of treatability studies: remedy screening, remedy selection, and remedy design. The "Guide for Conducting Treatability Studies Under CERCLA: Thermal Desorption" discusses all three levels of treatability studies.

Remedy screening studies provide a quick and relatively inexpensive indication of whether thermal desorption is a potentially viable remedial technology. Remedy selection studies provide data that permit evaluation of thermal desorption's ability to meet expected site cleanup goals and provide information in support of the detailed analysis of the alternative (i.e., seven of the nine evaluation criteria specified in EPA's RI/FS Interim Final Guidance Document, EPA/540/G-89/004, 1988). Remedy selection tests generally have moderate costs, and may require weeks to months to complete. Remedy design testing provides quantitative performance, cost, and design information for remediating the operable unit. Remedy design studies are of moderate to high costs and may require months to complete.

TECHNOLOGY DESCRIPTION AND PRELIMINARY SCREENING

Technology Description

Thermal desorption includes any number of ex situ processes that use either direct or indirect heat exchange to vaporize organic contaminants from soil and sludge. Air, combustion gas, or inert gas is used as the transfer medium for the vaporized components. Thermal desorption systems are physical separation processes and are not specifically designed to provide organic decomposition. Thermal desorption is not incineration, since the decomposition of organic contaminants is not the desired result, although some decomposition may occur. The concentrations of contaminants and the specific cleanup levels for the site will influence the technology's applicability for that site. System performance is typically measured by comparison of untreated soil/sludge contaminant levels with those of the processed soil/sludge. For the purpose of clarity and brevity in this report, the term medium will refer to contaminated soil, sludge, and sediment or combinations of these. The medium is typically heated to 200 to 1,000°F; based on the thermal desorption system selected, certain systems operate at higher temperatures.

An important operating design parameter is time-at-temperature, which is defined as the elapsed time that the average medium temperature is at or above the target temperature. Figure 1 is a general schematic of the thermal desorption process.

Materials handling (1) requires excavation and transport of the medium to the system. Typically, large objects greater than 1.5 inches are screened from the medium and rejected. Classified medium is conveyed, via belt or screw conveyor, to a feed hopper, and then metered into the desorber.

Significant system variation exists in the desorption step (2). The desorber can be a rotary dryer, a thermal screw, a distillation chamber, or a vapor extractor.

Contaminants are intimately contacted with a heat transfer surface or hot gases, and highly volatile components (including water) are driven off. An inert gas, such as nitrogen or-steam, maybe injected to convey the vaporized contaminants and water and to ensure contaminants are not oxidized by reducing the source of oxygen.

The actual medium temperature and residence time are the primary factors affecting performance in thermal desorption. These parameters can be controlled in the desorption unit by using a series of increasing temperature zones, multiple passes of the medium through the desorber where the operating temperature is sequentially increased, or separate compartments where the heat transfer fluid temperature is higher.

Offgas from desorption (3) will contain entrained dust (particulate) from the medium, vaporized contaminants, and water vapor. Particulates are removed by conventional equipment such as cyclones, fabric filters, or wet scrubbers. Volatiles in the offgas may be condensed and then passed through a carbon adsorption bed or other treatment system. Emissions may also be destroyed in an offgas combustion chamber or catalytic oxidation unit. The selection of the gas treatment system will depend on the concentrations of the contaminants, cleanup standards, and the economics of the offgas treatment system(s) employed.

Thermal desorption is most applicable for separation of organic contaminants from soils or sludges. Thermal desorption units have been selected in the ROD for one or more operable units at approximately 14 Superfund sites. These sites include: McKin (Maine), Ottati & Goss (New Hampshire), Cannon Engineering (Massachusetts), Resolve (Massachusetts), Wide Beach (New York), Fulton-Terminals (New York), Metaltec/Aerosystems (New Jersey), Caldwell Trucking (New Jersey), Outboard Marine/ Waukegan Harbor (Illinois), Reich Farms (New Jersey), Waldick Aerospace Devices (New Jersey), Wamchem (South Carolina), and two Stauffer Chemical sites in Alabama.

Prescreening Characteristics

The determination of the need for and the appropriate tier of treatability study required is dependent on the literature available on the technology, expert technical judgement, and site-specific factors. The first two elements–the literature search and expert consultation –are critical factors of the prescreening phase in determining whether adequate data are available or whether a treatability study is needed.

Information on the technology applicability, the latest performance data, the status of the technology, and sources for further information are provided in one of a series of engineering bulletins being prepared by EPA's Risk Reduction Engineering Laboratory in Cincinnati, Ohio.

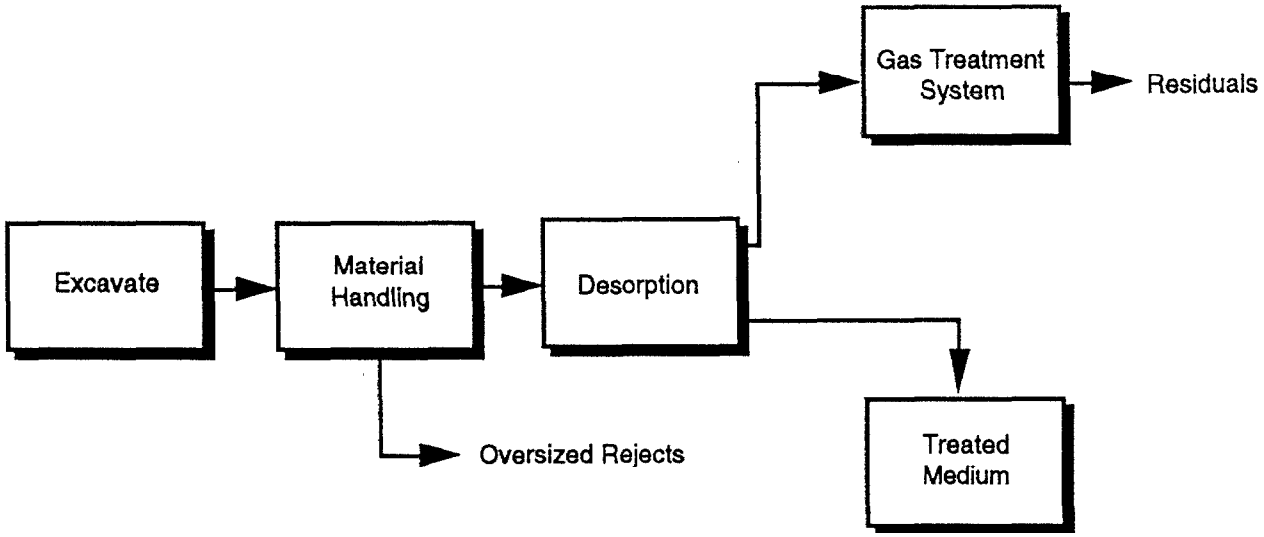

Figure 1. Schematic Diagram of Thermal Desorption

A literature search should be performed to determine the physical and chemical properties of the contaminants of interest. Contaminant characteristics such as volatility and density are important for the design of remedy screening studies and related residuals treatment systems. Particle size distribution and moisture content may be important to determine pretreatment needs. If enough information is obtained by prescreening to allow a decision to be made regarding the potential success of thermal desorption, remedy screening may be skipped.

If contamination exists at different soil zones, a soil characterization profile should be developed for each soil type or zone. Available chemical and physical data (including averages and ranges) and the volumes of the contaminated soil requiring treatment should be identified. For "hot spots," separate characterizations should be done so they can be properly addressed in the treatability tests if quantities are such that blending will not provide a homogeneous feed stream. Thermal desorption may be applicable to some parts of a site, but not to other parts.

Characterization test samples should be broadly representative of the contaminant profile of the site. Grab samples taken from the site ground surface may represent only a small percentage of the contaminated soils requiring remediation. Deeper, subsurface strata affected by contaminants may vary widely in composition, soil classification, total organic carbon, and contamination levels from those found at the surface, and should also be characterized so that the fractions of volatile organic compounds (VOCs) and semi-volatile organic compounds (SVOCs) can be identified as to their location and concentration. The quantity and distribution of rubble and debris at the site should also be determined as part of the characterization process. This material may have to be removed from the feedstock material during any full-scale treatment operations.

Technology Limitations

Thermal desorption limitations may be defined as characteristics that hinder cost-effective treatment. The primary technical factors affecting thermal desorption performance are the maximum bed temperature achieved, total residence time, organic and moisture content, contaminant characteristics, and medium properties. Since the basis of the process is physical removal from the medium by volatilization, bed temperature directly determines the endpoint concentration. The degree of mixing, where applicable, and the sweep gas rate also affect removal rate. In some cases, achieving and maintaining the desired results are too costly for sites that are heavily contaminated with organics or that have a high moisture content. If the system isdirect-heated, flammability of the contaminant must also be considered in order to prevent explosions. As in most systems that use a reactor or other equipment to process wastes, media exhibiting a very high pH (greater than 11) may corrode the system components. Media exhibiting low pH may similarly corrode system components during processing.

THE USE OF TREATABILITY STUDIES IN REMEDY EVALUATION

Treatability studies should be performed in a systematic fashion to ensure that the data generated can support the remedy evaluation process. The results of these studies must be combined with other data to fully evaluate the technology.

There are three levels or tiers of treatability studies: remedy screening, remedy selection, and remedy design. Some or all of the levels may be needed on a case-by-case basis. The need for and the level of treatability testing are management-based decisions in which the time and cost of testing are balanced against the risks Inherent in the decision (e.g., selection of an inappropriate treatment alternative). These decisions are based on the quantity and quality of data available and on other decision factors (e.g., state and community acceptance of the remedy, new site data, or experience with the technology).

Technologies generally are evaluated first at the remedy screening level and progress through remedy selection to the remedy design level. A technology may enter the selection process at whatever level is appropriate based on available data on the technology and site-specific factors. Figure 2 shows the relationship of the three levels of treatability study to each other and to the RI/FS process.

Remedy Screening

Remedy screening is the first level of testing. It is used to establish the ability of a technology to treat a waste. Remedy screening is generally low cost (e.g., $8,000 to $30,000) and requires several days to several weeks to complete. Time must be allowed for project planning, chemical analyses, interpretation of test data, and report writing. Limited quality control is required for remedy screening studies. These tests yield data indicating a technology's potential to meet performance goals and applicability to the specific waste sample. Remedy screening tests can identify operating parameters for investigation during remedy selection or remedy design. They generate little, if any, design or cost data and should not be used as the sole basis for selection of a remedy. Screening tests are conducted using laboratory-scale equipment. These tests are generic, not vendor-specific, and can be performed at any laboratory with the proper equipment and qualified personnel.

In some instances, thermal desorption remedy screening treatability studies can be skipped, if enough information about the physical and chemical characteristics of the contaminants and medium allow for evaluation of the potential success of thermal desorption at a site. Information on past performance with similar contaminants is useful in evaluating the potential applicability of thermal desorption. In such cases, remedy selection tests are normally the first level of treatability study executed.

Remedy Selection

Remedy selection is the second level of testing. Remedy selection studies identify the technology's performance for a site. These studies have a moderate to high cost (e.g., $10,000 to $100,000) and require several months or more to plan, obtain samples, and execute. Remedy selection studies yield data that verify that the technology can meet expected cleanup goals, provide information In support of the detailed analysis of alternatives, and give Indications of optimal operating conditions.

The remedy selection tier of thermal desorption testing consists of either bench-scale tests or pilot tests. Frequently these tests will be technology-specific. The key question to be answered during remedy selection testing is whether the treated medium will meet the cleanup goals for this site. The exact removal efficiency or acceptable residual contaminant level specified as the goal for the remedy selection test is site-specific. A remedy design study would follow a successful remedy selection study, although they are usually not conducted until after a Record of Decision (ROD) has been issued.

Remedy Design

Remedy design is the third level of testing and is done after the ROD. It provides quantitative performance, cost, and design information for an operable unit. This testing also produces the remaining data required to optimize performance. These studies are of moderate to high cost (e.g., $50,000 to $200,000) and require several months to complete. For complex sites (e.g.,sites with different types or concentration of contaminants indifferent medium such as soil, sludges, and sediments), longer testing periods maybe required, and costs can be higher. Remedy design tests yield data that verify performance to a higher degree than the remedy selection and provide detailed design Information. They are most often performed during the remedy design phase of a site cleanup.

TREATABILITY STUDY WORK PLAN

Carefully planned treatability studies are necessary to ensure that the data generated are useful for evaluating the validity or performance of the technology. The Work Plan sets forth the contractor's proposed technical approach to the tasks outlined in the RPM's Work Assignment. It also assigns responsibilities, establishes the project schedule, and estimates costs. The Work Plan must be approved by the RPM before work begins. A suggested organization of the thermal desorption treatability study Work Plan is provided in the "Guide for Conducting Treatability Studies Under CERCLA: Thermal Desorption."

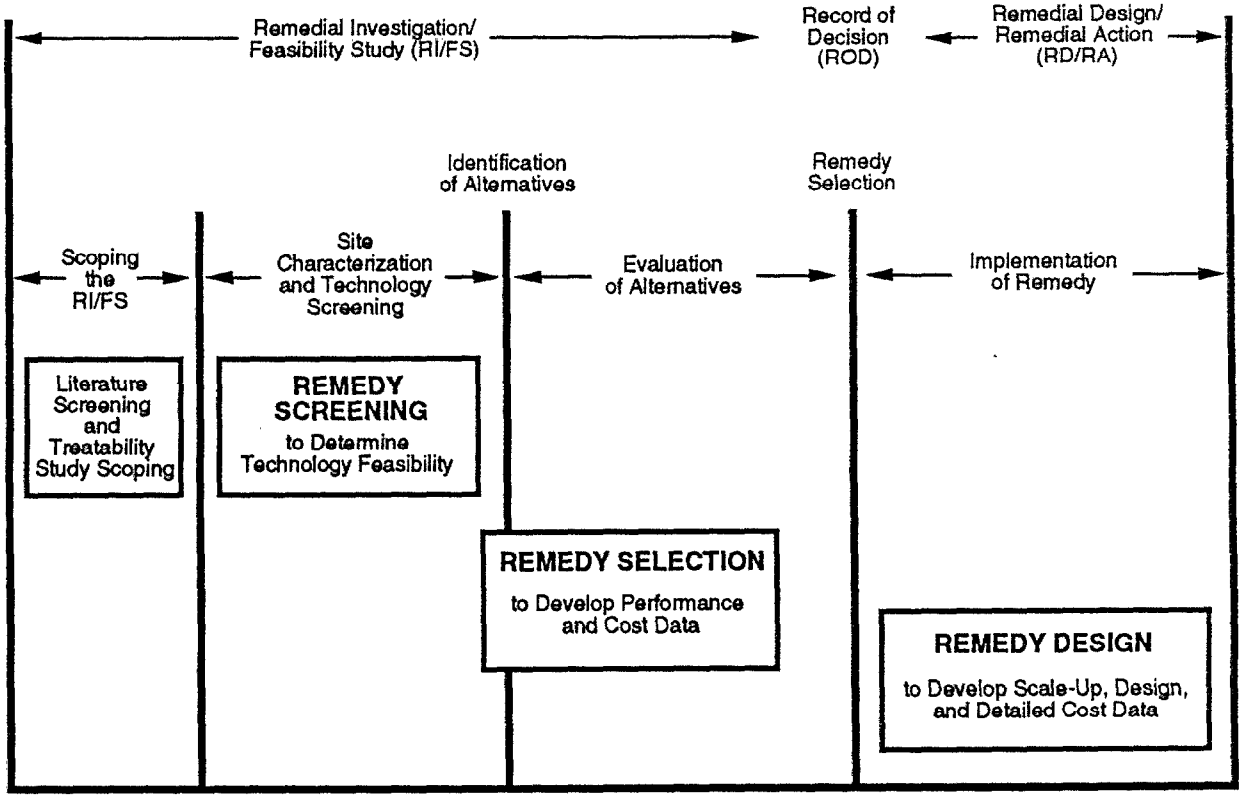

Figure 2. The Role of Treatability Studies in the RI/FS and RD/RA Process

Test Objectives and Goals

The overall thermal desorption treatability study objectives must meet the specific needs of the RI/FS. There are nine evaluation criteria specified in EPA's RI/FS Interim Final Guidance Document (OSWER-9335:301). Treatability studies can provide data from which seven of these criteria may be evaluated.

Setting goals for the treatability study is critical to the ultimate usefulness of the data generated. Objectives must be defined before starting the treatability study. Each tier of treatability stud needs performance goals appropriate to that tier. For example, remedy selection tests are used to answer the question, "Will thermal desorption work on this medium/contaminant matrix?" It is necessary to define "work" (e.g., set the goal of the study). The remedy selection test measures whether the process has the potential to reduce contamination to below the anticipated performance criteria to be specified In the ROD. This may indicate that further testing for remedy design is appropriate.

When remedy screening tests are performed, defining the minimum temperature of the medium and residence time needed to achieve the required cleanup criteria are the desired goals. The remedy screening treatability study goals must be determined on a site-specific basis. Typically, achievement of 75 percent or higher separation efficiencies in the remedy screening tier would justify proceeding to the next tier. RREL's Remedy Screening Lab has used 50 percent as a goal in the past.

The main goals of the remedy selection tier of testing are to obtain information on operating parameters relevant to a full-scale thermal desorption system. Inclusive in these goals are determining actual contaminant concentrations achieved after treatment, definition of the heat input requirements and average bed temperatures achieved, as well as limited performance data for the off gas treatment system(s) thought to be applicable to the medium/contaminant matrix. The actual goal for separation efficiency must be based on site- and process-specific characteristics. Typical separation efficiencies are 90 percent and higher. The specified separation efficiency must meet site-specific cleanup goals, which are based on a site risk assessment.

Experimental Design

Careful planning of experimental design and procedures are required to produce adequate treatability study data. The experimental design must identify the critical parameters and determine the number of replicate tests necessary. System design, test procedures, and test equipment will vary among vendors. The information presented in this section provides an overview of the test equipment and procedures as these relate to each type.

When considering remedy screening tests, a number of systems can be used such as a static tray or differential bed reactor (DBR). In the tray test, contaminated medium is heated in a muffle furnace equipped with an electronic temperature controller. The furnace should be capable of achieving an internal temperature up to 1,400'F with a relatively fast heat-up rate. The depth of the soil should be kept at a minimum to eliminate temperature and concentration gradients within the soil bed. The temperature of the medium should be monitored very closely, and care should be taken that the thermocouple(s) are completely immersed in the solid material. The time to reach a target treatment temperature should be minimized to practical laboratory time frame such as 5 to10 minutes. Longer time may be required depending on the specific contaminants present in the soil.

In a DBR, a thin bed of medium is placed in a furnace between two screens. Preheated gas passes through the bed which eliminates concentration and temperature gradients within the bed. In this reactor, the temperature of the medium should also be monitored and the bed should reach its target temperature within 5 to 10 minutes.

Remedy screening tests alone do not produce enough information to perform an economic analysis of a thermal desorption process, but do generate data on time-at temperature requirements. (Time-at-temperature is defined as the elapsed time that the average medium temperature is at or above a target temperature.) To reduce analytical costs during the remedy screening tier, the list of known contaminants must be reduced to a few key compounds selected as indicators of performance. Mass balance calculations are usually limited by analytical results on solids and liquid feed and discharge streams during remedy screening. Normally, gaseous emissions are not tested at this level.

Remedy selection testing is intended to more accurately estimate the performance of a full-scale thermal desorption system. The tests may be conducted in either batch or continuous treatment systems that simulate the heat and mass transfer characteristics of specific full-scale thermal desorption processes. Data collected at this level can be used to model thermal desorption under various experimental conditions. Information from modeling can then be used to predict time and temperature requirements in full-scale operating systems. Remedy selection test systems are able to simulate the performance characteristics of the various desorption systems.

Remedy selection testing should define the time- at-temperature and residual concentrations as a function of heat input and bed mixing characteristics for a thermal desorption device.

More precision is used in weighing and mixing of the sample with an associated increase in QA/QC costs as compared to remedy screening tests. Further care must be taken to ensure homogeneity of the sample(s) being treated. Holding time of media and off gas samples in the lab before extraction and analysis can be an important consideration for some contaminants. At this phase of remedy selection, it is recommended that duplicate (or triplicate) test runs are completed to ensure reproducibility of the results. This is extremely important when non-vendor (generic) tests are performed (i.e., DRB or static trays). This series of tests is considerably more costly than remedy screening tests, so only sites with contaminated medium that show promise in

the remedy screening phase should be carried forward into the remedy selection tier.

Variables that should be documented and/or controlled during this level of treatability testing include:

- moisture content of medium
- contaminant concentration in medium
- particle size of medium
- treatment temperature or minimum solids temperature
- time-at-temperature or total residence time
- medium physical or chemical characteristics
- thermal properties of medium
- degree of agitation (solid/gas mixing).

The moisture content of the medium affects throughput rate due to the energy requirements for drying. A high water concentration delays contaminant volatilization or requires larger heat inputs to remove contaminants from the medium if the same throughput is to be maintained. Treatability testing should be performed with medium samples that represent the average moisture content expected during full-scale thermal desorption operations.

Samples should be representative of site conditions for the range of concentration of contaminants. Variability in contaminant concentration should be expected within individual samples used to characterize the extent of contamination at the site. Blending waste material into a more homogeneous mixture is useful for treatabiility testing.

The particle size distribution of the medium for the test must approximate that expected for the contaminated volume to be treated. If a significant amount of foreign objects; large, consolidated chunks of medium; or significant medium heterogeneity exist at the site, this may impact the selection. This may also indicate the need for additional materials handling equipment if the next tier of testing is conducted. Thermal desorption treatability tests are normally conducted at temperatures within the operating ranges of full-scale thermal desorption systems. This temperature range is normally between 200EF and 1,000EF for the medium.

The decision on whether to perform remedy selection testing on hot spots or composite soil samples is difficult and must be made on a site-by-site basis. Hot spot areas should be factored into the test plan if they represent a significant portion of the waste site. However, it is more practical to test the specific waste matrix that will be fed to the full-scale system over the bulk of its operating life. If the character of the medium changes radically over the depth of contamination, then tests should be designed to separately study system performance on each medium type. It may be necessary to Identify extreme conditions and determine the degree of blending required.

SAMPLING AND ANALYSIS PLAN

The Sampling and Analysis Plan (SAP) consists of two parts-the Field Sampling Plan (FSP) and the Quality Assurance Project Plan (QAPP). The RI/FS requires a SAP for all field activities. The SAP ensures that samples obtained forcharacterization and testing are representative and that the quality of the analytical data generated is known and appropriate. The SAP addresses field sampling, waste characterization, and sampling and analysis of the treated wastes and residuals from the testing apparatus or treatment unit. The SAP is usually prepared after Work Plan approval.

Field Sampling Plan

The FSP component of the SAP describes the sampling objectives; the type, location, and number of samples to be collected; the sample numbering system; the equipment and procedures for collecting the samples; the sample chain-of-custody procedures; and the required packaging, labeling, and shipping procedures.

Quality Assurance Project Plan

The QAPP should be consistent with the overall objectives of the treatability study.

The Project Description clearly defines and distinguishes the critical measurements from other observations and system conditions (e.g., process controls, operating parameters, etc.) routinely monitored. Critical measurements are those measurements, data gathering, or data generating activities that directly impact the technical objectives of a project. At a minimum, the determination of thetarget compound in the initial and treated solids samples, medium temperature, and time-at-temperature will becritical measurements for remedy selection tests. Concentration of target compounds in all fractions will be critical measurements for remedy design tests.

The purpose of the remedy selection treatability study is to determine whether thermal desorption can meet cleanup goals and provide information to support the detailed analysis of alternatives (i.e., seven of the nine evaluation criteria). A higher level of QA/QC is required because the consequences of an incorrect decision are more serious. Concentrations of the target contaminants in the soil should be verified by using matrix spikes. The QAPP should address the measurement of critical variables, including the concentrations of target compounds in the initial and treated soil for remedy selection column tests.

The methods for analyzing the treatability study samples are the same as those for chemical characterization of field samples. Preference is given to methods in "Test Methods for Evaluating Solid Waste", SW-846, 3rd. Ed., November 1986. Other standard methods may be used, as appropriate. Methods other than gas chromatography/spectroscopy (GC/MS) techniques are recommended to conserve costs when possible.

TREATABILITY DATA INTERPRETATION

To properly evaluate thermal desorption as a remediation alternative, the data collected during remedy screening and remedy selection phases must be compared to the test goals and other criteria that were established before the tests were conducted.

Remedy screening treatability studies are designed to gain fundamental information regarding the proof of concept for the technology. Tests are typically conducted using laboratory equipment such as a static tray, or DBR, or other screening devices. The contaminant concentration in the medium, before treatment is compared to the contaminant concentration after treatment. If the measured separation efficiency is sufficient, additional treatability studies are warranted. If the operating parameters are properly selected, separation efficiency can be high. This would indicate success on the screening level, and testing should proceed to remedy selection. If remedy screening tests are conducted at lower temperatures and/or shorter treatment times than those discussed in the experimental design, removal efficiencies maybe lower. It may not be appropriate to eliminate thermal desorption as a treatment alternative under such cases, since screening tests maybe redesigned under different conditions to demonstrate higher removal efficiencies. At certain sites, removal efficiencies less than 90 percent maybe acceptable in meeting expected cleanup goals and testing can proceed to remedy selection. Before and after concentrations can normally be based on duplicate samples for each test run. The mean values from these analyses are compared to assess the success of the study.

The goals of remedy selection are to address general medium pretreatment and materials handling requirements, to estimate performance and cost data of full scale systems, to verify that thermal desorption can meet cleanup levels at normal operating conditions, and to define heat input requirements, and to address general offgas treatment and residuals disposal requirements.

Data obtained from remedy selection need to be interpreted with a scale-up tool (i.e., past experience or computer simulation). Vendors use past experience to scale-up to their own systems. A computer simulation scale-up tool is the GRI/NSF Thermal Treatment Model being developed at the University of Utah to describe the decontamination of a solid medium when heated in a rotary kiln. The model describes the heat transfer to the contaminated medium and the desorption of the contaminant from the medium and its subsequent fate in the gas phase.

The model, which is not vendor specific, has been used to predict the performance of full-scale systems from data generated in treatability studies. It provides an ideal method for the interpretation of both remedy selection and remedy design data, but it is relevant to rotary dryer desorption systems only.

TECHNICAL ASSISTANCE

Additional literature and consultation with experts are critical factors in determining the need for and ensuring the usefulness of treatability studies. A reference list of sources on treatability studies is provided in the "Guide for Conducting Treatability Studies Under CERCLA: Thermal Desorption"

It is recommended that a Technical Advisory Committee (TAC) be used. This committee includes experts on the technology who provide technical support from the scoping phase of the treatability study through data evaluation. Members of the TAC may include representatives from EPA (Region and/or ORD), other Federal Agencies, States, and consulting firms.

OSWER/ORD and the regions operate the Technical Support Project (TSP) which provides assistance in the planning, performance, and/or review of treatability studies. For further information on treatability study support or the TSP, please contact:

Engineering Technical Support Center
Risk Reduction Engineering Laboratory (RREL)
Cincinnati, OH
Contact: Ben Blaney
(513) 569-7406

FOR FURTHER INFORMATION

In addition to the contacts identified above, the appropriate Regional Coordinator for each Region located in the Hazardous Site Control Division/Office of Emergency and Remedial Response or the CERCLA Enforcement Division/Office of Waste Programs Enforcement should be contacted for additional information or assistance.

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